Before the
FEDERAL COMMUNCATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Application of Space Exploration Holdings, LLC, For Modification of Authorization for the SpaceX NGSO Satellite System	)))))	 File No. SAT-MOD-20200417-00037

To: The International Bureau

PETITION TO DENY OF KEPLER COMMUNICATIONS INC.

Kepler Communications Inc. ("Kepler") hereby submits this Petition to Deny to the modification ("Modification") of Space Exploration Holdings LLC ("SpaceX"), to inform on its finding that the Modification as proposed will significantly increase the overall interference environment for some systems, including Kepler's.[1] Kepler speculates that such impacts would apply similarly to any system in the Ku-band with substantial polar operations, or that employs minimum earth station elevation angles below 40° – at least for small station types. Kepler also echoes the concerns of Astroscale regarding orbital debris risk, and the need for an adequate interference assessment of the Modification. Given the complex nature of the subject, it is not clear that some of the benefits of bringing 2,824 satellites down to the 500 km range, including natural de-orbit, necessarily make up for the changes in the orbit configuration. The Commission should request, as it has with other operators, an assessment of aggregate risk at all orbit regimes, and at

[1] *See* Application of Space Exploration Holdings, LLC, For Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20200417-00037 (Apr. 17, 2020).

presumptive failure rates of 5, 10, and 15 percent.[2] Kepler also requests that the Commission ask SpaceX to specify which ITU filing or filings will be used for the modified system as such information will be significant when determining interference at the ITU. For both physical and frequency coordination affairs in general, Kepler agrees with SpaceX that optimal solutions will ultimately come out of specific coordination agreements between operators. While Kepler continues to work to achieve mutually satisfactory agreements with other NGSOs, SpaceX's ever-changing constellation has made it difficult to meaningfully progress an assessment and hence conclude an agreement. Given the findings demonstrated herein, Kepler does not agree with SpaceX's claim that no more interference is caused to other operators, including Kepler's.

I. THE MODIFICATION WILL CAUSE AN INCREASE IN INTERFERENCE TO SOME SYSTEMS

The Commission has stated that it will grant any request for modification provided it does not, *inter alia*, render the applicant unqualified to operate a space station nor harm the public interest, convenience and necessity. It has previously recognized that a modification that would raise significant interference problems would act to harm the public interest, and that to be granted, modifications must demonstrate that they will not raise such interference.[3] To this end, SpaceX claims that its modification will "cause no material overall increase in radiofrequency interference".[4] To support its claim, SpaceX points to the reduction of total satellites from 4409 to

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[2] The Commission requested that Kuiper Systems LLC provide with its Part 25 application "an aggregate collision risk estimate for all satellites planned for launch, assuming satellite failure rates (failures that result in loss of maneuver capability) of 5, 10, and 15 percent". Letter from Jose P. Albuquerque to C. Andrew Keisner, IBFS File No. SAT-LOA-20190704-00057 (Aug. 19, 2019).

[3] *Teledesic LLC*, 14 FCC Rcd. 2261, ¶ 5 (IB 1999) ("In recognition of the several years required to construct a satellite, or constellation of satellites, the rapidly changing technology, and our goal of encouraging more efficient use of the radio spectrum, the Commission has tried to allow licensees to modify their satellite systems when possible. […] If the proposed modification does not present any significant interference problems and is otherwise consistent with Commission policies, it is generally granted.").

[4] *See* Modification, Technical Supplement at 1.

4408; their mass relocation to a lower altitude, resulting in fewer satellites in the sky at any given time (which they claim will reduce inline events); and requiring lower EIRP levels to close links with the ground.[5] Kepler acknowledges that the reduction in altitude, leading to a lower EIRP requirement may have a neutral impact on the interference environment. However, critically undiscussed is the impact from two other key changes of the modification: the particular restructuring of the orbital planes, and the lowering of the user terminal minimum elevation angle from 40° to 25°. The first change, relating to SpaceX's restructuring of its orbital planes, has concentrated more satellites in northern regions, a service area critical to Kepler's operations. Moreover, many of these newly proposed orbits are now closely aligned with those of Kepler both in altitude and inclination, and Kepler's analyses find that the modification actually acts to increase the number and duration of inline events, counter to SpaceX's claim (Figure 1 below).

[5] *See* Modification at 16.

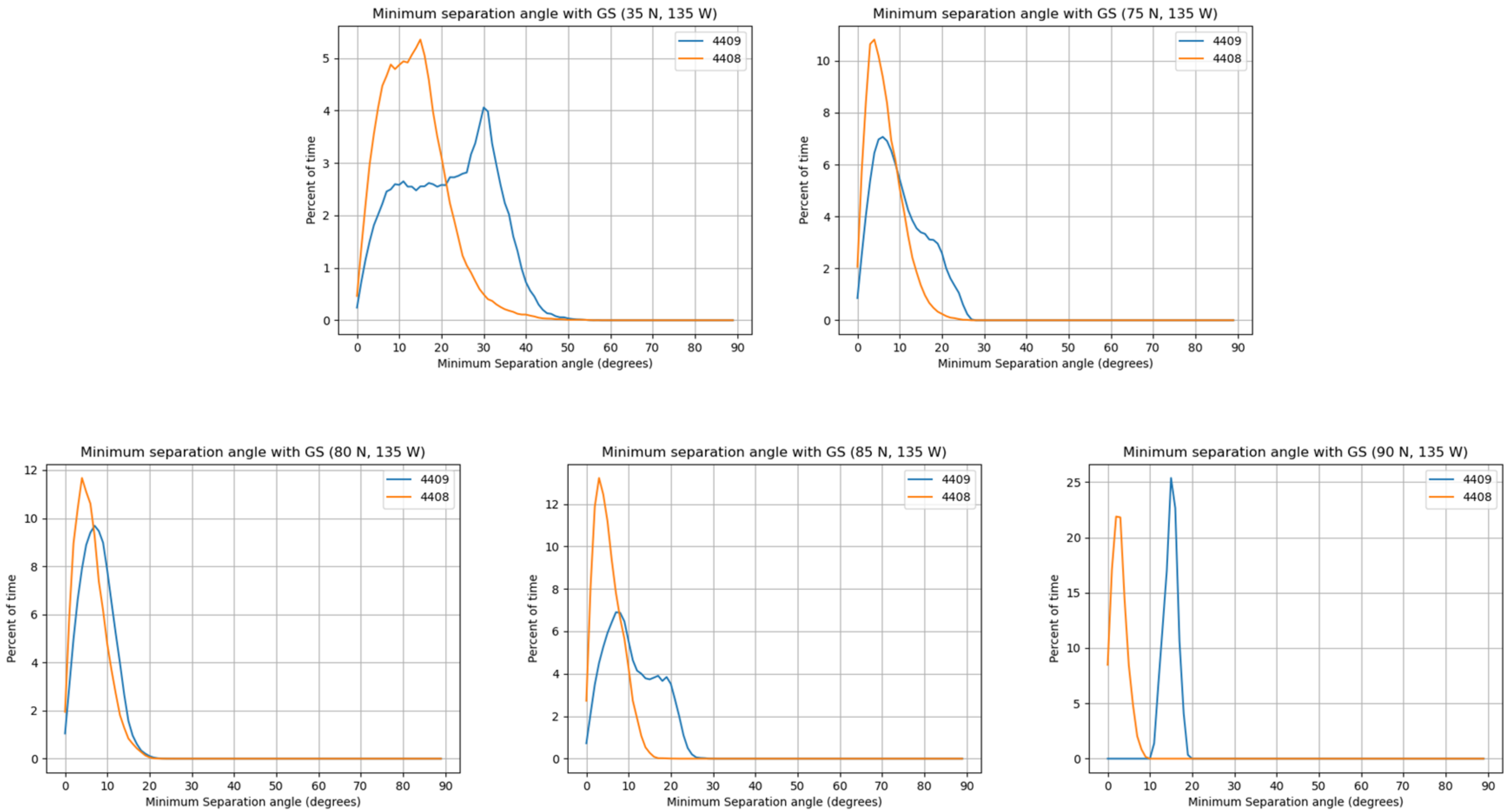

Figure 1: Minimum separation angle between the set of visible SpaceX and Kepler satellites over a victim ground station, measured once per timestep and aggregated over a simulation period of 5 days. Results show the average, dynamic proximity of SpaceX and Kepler satellites from ground stations located at 35°, 75°, 80°, 85°, and 90° latitude. In all circumstances, the Modification (designated as 4408 based on the total number of satellites in the system, in orange) spends more time near Kepler's satellites than the current SpaceX authorization (4409 satellites, in blue). The Modification therefore brings SpaceX satellites in closer proximity to Kepler satellites overall, thereby increasing total in-line time.

From Figure 1, it is clear that SpaceX's statement that its modification "will not increase the likelihood of exceeding the Commission's -12.2 dB (6% ΔT/T) threshold" is verifiably untrue. The second parameter, minimum elevation, plays a critical role in any assessment of interference, because it determines the fraction of interfering satellites in the sky that are to be actively transmitting or receiving at any given time. There may be fewer satellites in the sky overall, but a greater portion of them may be actively transmitting or receiving. Additionally, SpaceX increases its satellite EIRP as they move through these lower elevations (see Figure 2 below).

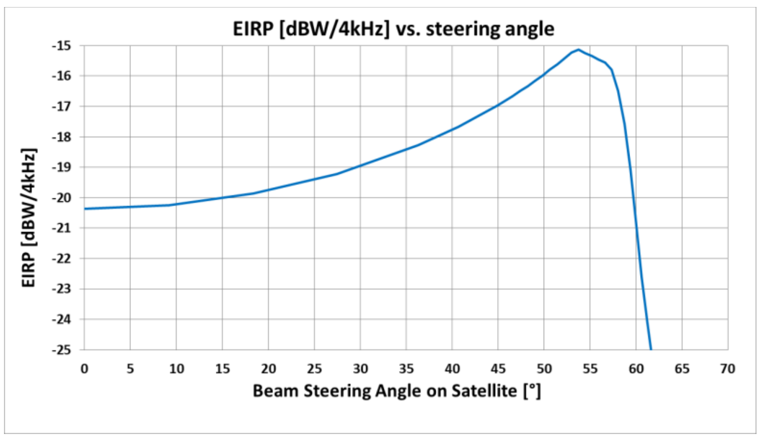

Figure 2: SpaceX plot showing EIRP Density Variation by Beam Steering Angle at 540 km.[6]

SpaceX performed an analysis to support its claims, but its selection of example victim systems was not representative enough to fully evaluate the effects of its modification, particularly the two aforementioned key parameters. SpaceX assessed the dynamic, time-varying interference generated into three example systems: OneWeb, Telesat and O3b, to show that the modification would not substantially increase observed I/N.[7] SpaceX's assessment to these systems yielded mixed results – which was acknowledged – with an increase in interference being observed

[6] *See* Modification at 6.
[7] *See* Modification, Technical Supplement at 16. ("[The] analysis, set forth in Annex 2 to this Technical Attachment, demonstrates that the modification would have no material effect on the interference environment of other NGSO systems.").

predominantly in high I/N regimes (interference-dominated environments). SpaceX excuses this increase by noting that, under Commission rules, communication in such regimes would be already subject to default band-splitting procedures because they would occur beyond the sharing trigger of $\frac{\Delta T}{T} = 6\%$, after which coordination is required.[8] SpaceX concludes therefore that no effective increase in interference is caused.

At first glance this argument seems plausible, but it fails to account for several important effects. In the case of Kepler's system, SpaceX's modification increases the frequency of inline events – resulting in more time spent using the band splitting mechanism (absent other agreements). Operators of large constellations can be insulated from the downsides of this effect; during an in-line event when a smaller operator would have to split the band, a larger operator with sufficient satellite diversity might be able to simply use one of its other satellites in view to serve the location. In this way, only the smaller operator experiences the limits of the sharing exchange. For illustrative purposes, one could call this an "asymmetrical" event. In contrast, an event where both operators experience the same effective burden of the band splitting event could be called a "standard" event. A higher frequency of in-line events may not substantially affect SpaceX's operations, but it does for smaller systems like Kepler's. In theory, a large operator could exploit this effect to reduce the viability of other constellations. Indeed, a large enough constellation could crowd out a smaller one by triggering in-line events at a near-constant rate, without so much burdening its own operations at all.

SpaceX performed its interference assessment for systems that operate in both Ku-band (OneWeb) and Ka-band (Telesat, O3b). However, Kepler's Ku-band system is not adequately

[8] See 47 C.F.R § 25.261.

represented by SpaceX's use of the OneWeb system as its model. Kepler's system employs user terminals with a minimum elevation angle of 10 degrees, and so is sensitive to modification of SpaceX minimum elevation thresholds. OneWeb, with minimum user terminal elevation angles of 40 degrees, is not. Further, Kepler's satellites are in high-inclination, sun-synchronous orbits. The Modification has added 520 satellites into sun-synchronous orbits, nearly identical to Kepler's, where none had previously been assigned. Such changes have significant effects on the frequency and character of in-line events.

Of course, a quantitative analysis is required to assess the net impact of these results. Therefore, Kepler has also performed a dynamic, time-varying interference analysis between its own system and the modified SpaceX system as proposed. Importantly, Kepler used all the same general assumptions as SpaceX did for its analyses, including that antennas are assumed to be randomly pointed, and that the two systems do not implement any interference mitigation strategies, among others.[9] The results indicate that the reduction of minimum elevation from 40° to 25°, the increase in EIRP, and the additional changes made to the system orbital configuration, significantly worsen the interference conditions in all environments (noise- and interference-dominated).

[9] *See* Modification, Annex 1 of Technical Supplement at A1-2 to A1-3.

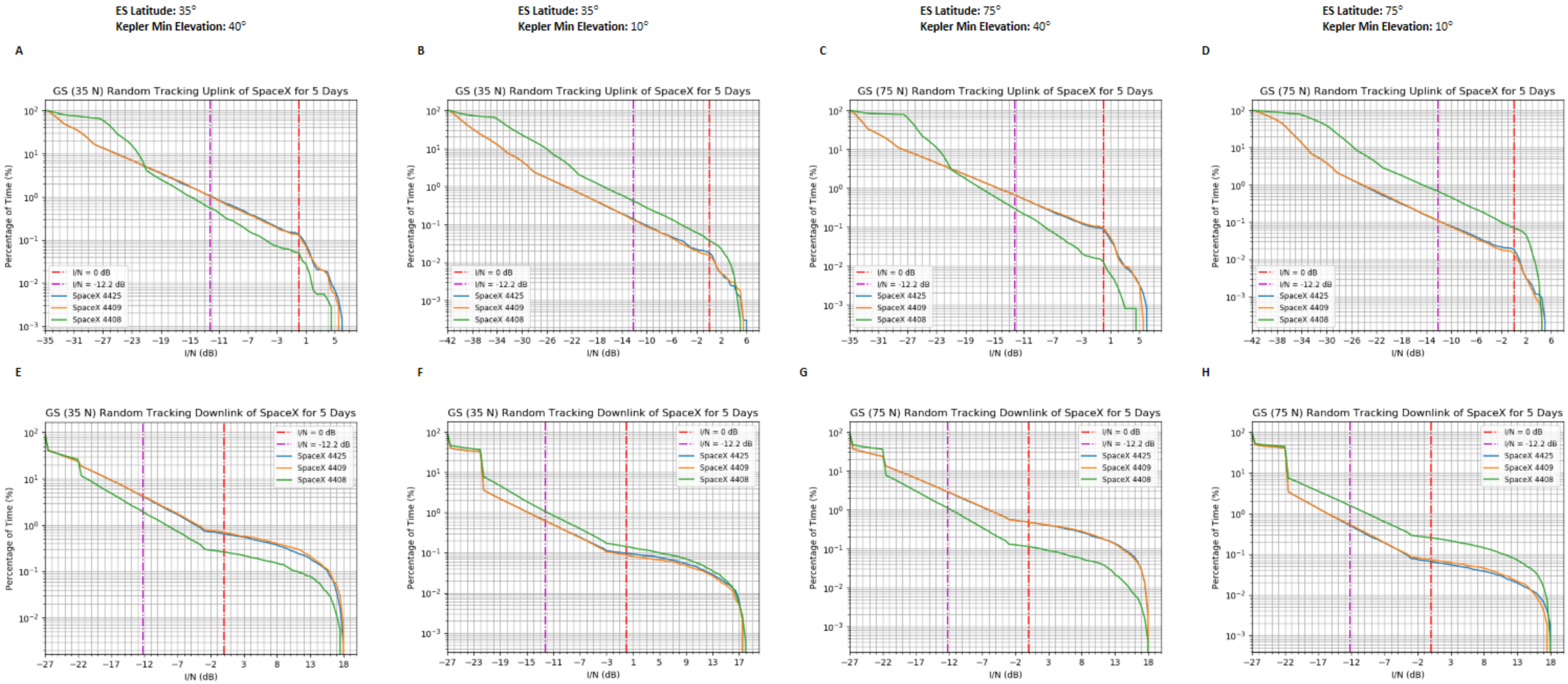

Figure 3: I/N CDF shown for uplink/downlink interference assessments using several versions of SpaceX's system, as originally filed or later modified, against Kepler's system. The effects of the current modification are shown in green, with comparisons to older SpaceX filings in orange and blue. Ground stations were modelled at 135°W longitude.

These results were obtained by using the same criteria that SpaceX used for its own analysis, modelled with earth stations at 35° and 75° latitude respectively. Kepler performed four sets of simulations to assess the effects of changing earth station altitude and minimum elevation. The results show the following:

- To properly illustrate the effects that were not captured by SpaceX's comparison to OneWeb, Figure 3-A, -C, -E and -G show what the interference environment would look like if Kepler's system also used a minimum elevation angle of 40°. It is clear that even in this highly conservative case that interference will still notably increase in low I/N regimes, particularly in the uplink direction.
- We find that when Kepler's actual elevation mask of 10° is used, the Modification produces substantially more interference in both directions.
- Interference further increases when a victim earth station is located at higher latitudes.

To further investigate worst-case scenarios beyond the 35° and 75° latitudes, Kepler modeled the I/N for earth stations at latitudes of 80°, 85°, and 90°. Minimum earth station elevation angle was kept at 10° (nominal). It should be noted that high latitude regions represent an important area for the delivery of Kepler's service, as its network is used to provide connectivity to the poles. Thus, such worst-case scenarios are squarely within Kepler's actual commercial operating parameters and in actual fact represent existing service commitments.[10]

[10] *See* Fierce Wireless, *Kepler delivers 120 Mbps uplink to Arctic via satellite broadband*, Nov. 8 2019. URL: https://www.fiercewireless.com/tech/kepler-delivers-120-mbps-uplink-to-arctic-via-satellite-broadband

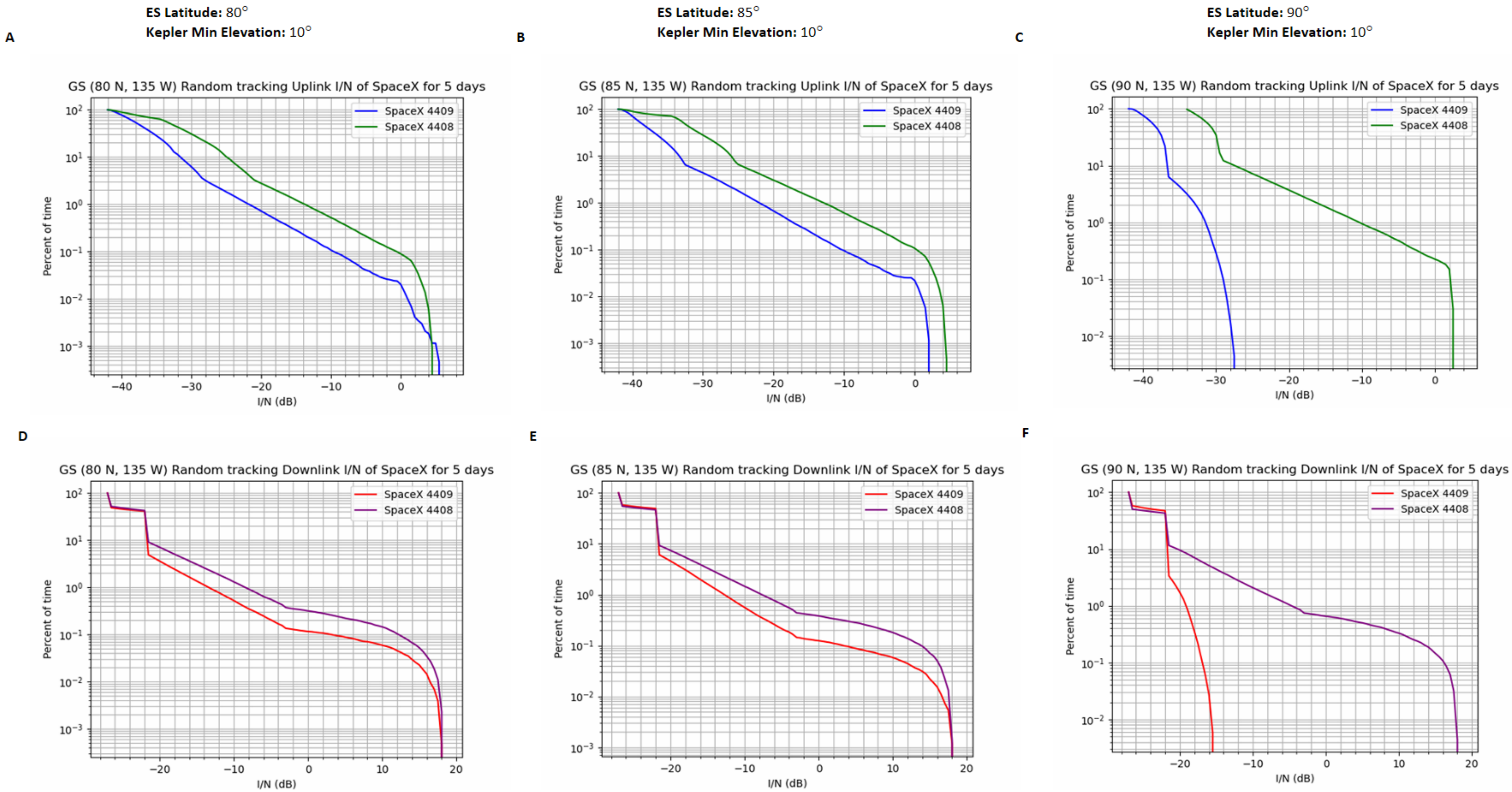

Figure 4: I/N CDF for SpaceX - Kepler interaction at high latitudes. Assessments are shown for victim earth stations located at 80°N, 85°N, and 90°N latitude.

The results from Figure 3 and Figure 4 show that for a Ku-band system sensitive to minimum elevation, interference is increased in all environments, whether noise- or interference-dominated, and whether at low or high latitudes. Interference is especially profound in high-latitude regions.[11] In all cases when using Kepler's true elevation mask of 10°, significant interference occurs before reaching the standard coordination trigger of $\frac{\Delta T}{T} = 6\%$, in contradiction to SpaceX's statements.[12] Unfortunately, SpaceX's modification does not meet the standards set by the Commission in the Teledesic case, as it presents significant interference problems. A reduction in total number of satellites by one and an overall reduction in altitude are evidently not enough to offset the increased aggregate interference produced by SpaceX's reduced minimum elevation angle, progressively increasing EIRP, and new orbital reconfiguration. The results imply that SpaceX's modification as proposed will inevitably produce more interference to some systems. Moreover, SpaceX's assessment failed to adequately identify the possible scenarios that might be impacted by its changes. Therefore, given the significant increase in interference caused to its system, Kepler cannot agree to the modification as proposed and asks the Commission to rule, in accordance with its precedent, that the Modification does not meet the public interest criteria required under § 25.117(d)(2)(ii) and to deny it.

[11] This can be understood geometrically: under SpaceX's existing authorization of 1,584 satellites at 53°, an earth station positioned at 90° latitude would only ever see SpaceX satellites arrive at a maximum elevation angle of about 45°. Under the present authorization SpaceX uses a minimum elevation angle of 40°, leaving only a 5° window to operate at the polar extremes. Due to this small window, the interference generated by SpaceX's current system to a Kepler victim station is relatively small (blue/red lines in Figure 4-C and Figure 4-F). However, the movement of 520 satellites into new polar orbits will naturally increase the interference potential in this area greatly, as SpaceX satellites will be able to trigger in-line events from every position in the sky (green/purple lines in Figure 4).

[12] *See supra* at note 9.

II. THE NET EFFECT OF THE MODIFICATION ON THE ORBITAL DEBRIS ENVIRONMENT CANNOT BE PROPERLY CONSIDERED ABSENT A FULL COLLISION RISK ASSESSMENT

Kepler recognizes that the Commission's ongoing orbital debris rulemaking is considering a substantial body of reforms to debris mitigation practices. Kepler has previously voiced its concerns for the approval of large new systems without performing a proper orbital debris assessment, concerns which are broadly shared by constituents of the space community. The recent letter submitted to the Modification by Astroscale has further highlighted the dangers posed by overlooking collision risk assessments.[13] Astroscale provides new detail on the Commission's longstanding zero-risk assumption – that satellites deemed 'capable of maneuvering' are considered to have an orbital collision risk of zero – and how it breaks down in large systems. It effectively assumes that collisions are impossible, a dangerous assumption at a time when proposed constellations by SpaceX alone vastly outnumber the total number of tracked objects in space, at all altitudes.[14] Moreover, the ability to reliably avoid collisions can only ever be as good as a system's ability to identify them, determined by the accuracy of its Space Situational Awareness (SSA). NASA has identified limitations to SSA as a major orbital debris problem which, while it can be improved, cannot be made perfect. It is well known that small debris of the kind that is undetectable by conventional SSA systems can still pack enough kinetic energy to disable a spacecraft in orbit, leaving it a dead object or worse, a series of dead object fragments.[15]

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[13] Letter from Charity Weeden to Marlene H. Dortch, IBFS. File No. SAT-MOD-20200417-00037 (Jun. 30, 2020).

[14] SpaceX and OneWeb have recently filed for constellations of 30,000 and 47,000 satellites respectively, on top of existing filings for 12,000 and roughly 2,600 satellites each. Between the two operators alone, over 90,000 satellites are proposed. According to NASA, in 2017 the total number of tracked objects in space exceeded 21,000. *See* NASA.gov, *Space Debris and Human Spacecraft*, (updated Aug. 7, 2017) URL: https://www.nasa.gov/mission_pages/station/news/orbital_debris.html

[15] The 2007 intentional destruction of Fengyun-1C and the 2009 collision of Iridium-33 and Cosmos-2251 were the two worst debris generating events in history, each spawning fields of roughly 3000 and 2000 trackable pieces of debris respectively. *See* NASA Technical Reports Server, *USA Space Debris Environment, Operations, and Policy Updates*, Feb. 2011 at 10.

Given the tight 30 km volume of SpaceX's proposed shell, and its direct overlap with currently authorized systems (including Kepler's), we naturally must concern ourselves with new risks that the Modification will introduce, its impact on our own system, and on the health of the orbital neighborhood. We ask therefore, that SpaceX demonstrate in detail its plans to mitigate its collision risk, as was required for the rest of NGSO applicants. We ask that SpaceX include a quantification of how much risk its system would produce in the unlikely event that its satellites were to experience a loss of maneuverability on orbit. In line with previous Commission requests, maneuverability failure rates of 5, 10, and 15% should be assumed.[16]

As Astroscale points out, the Modification would result in an 8-fold increase in orbital mass density of this particular 30 km shell, relative to current levels. Given the sheer size of the system, anything less than exceptionally high maneuverability and accidental explosion standards will be statistically very likely to generate at least one breakup event. SpaceX's statement that it will achieve 100% post-mission reliability is, as Astroscale suggests, "rather specious", because it does not provide any information on the maneuver reliability of its spacecraft (the primary clause justifying the zero-risk assumption). SpaceX should provide information sufficient to assess and understand this reliability.[17] Regarding accidental explosions, the NASA Orbital Debris Program Office recently completed a study to assess the fragmentation potential of large constellations as a function of accidental explosion probability.[18] It was found that counting fragmentation events from internal explosions alone (*i.e.* ignoring contributions from debris impacts), a

[16] *See supra* at note 2.
[17] *See Mitigation of Orbital Debris in the New Space Age*, Further Notice of Proposed Rulemaking, Report and Order, IB. Docket 18-313, FCC 20-54 (rel. Apr. 24, 2020) at ¶51. (Requiring operators to disclose the "extent of maneuverability of the planned space stations". This was broadly supported, and the Commission moved to adopt this practice.)
[18] *See* NASA Technical Reports Server, *Risk of Increased Fragmentation Events Due to Low Altitude Large Constellation Spacecraft*, Dec. 9 2019 ("Large Fragmentation Study").

megaconstellation similar to that of SpaceX could trigger tens to hundreds of new breakup events over its lifetime, depending on its accidental explosion rate. Based on its findings, NASA recommended that "[s]pacecraft should demonstrate that there is no credible failure mode for accidental explosion". The Commission should require as much, especially so for large constellations due to the risk of a systematic failure mode inherent in a given satellite design. In the Large Fragmentation Study, NASA warns of "a risk of accidental explosions that could take place during the constellation lifetime that should not be ignored. Since spacecraft in the same [large constellation] are likely to share similar, if not identical, designs and fabrication processes, a flaw leading to explosions could potentially exist in many spacecraft and might not be identified until years after launch or operations in orbit.".[19]

Considering the findings of the ODPO, the potential of a 260-kg satellite to produce many fragments upon breakup, and the rapidly increasing spatial density of this altitude region, we do not believe it unreasonable, nor alarmist, to worry about the potential to form a powder-keg orbit, with which a single moderate or large breakup event could spark a catastrophic debris cascade.[20] Indeed, researchers conceded in 2006, before the Fengyun-1C and Iridium-Cosmos break-ups, that the critical mass had been passed and a slow-burn Kessler syndrome was already underway.[21] With

[19] *See* Large Fragmentation Study at 2.

[20] For further information on satellite fragmentation potential and how mass affects the debris environment more broadly, *see* Darren Garber, et al., *Responsible Behavior for Constellation and Clusters*, Space Traffic Management Conference (Jan. 15, 2018). The study identifies several large clusters of derelict, non-functional debris that currently exist in LEO. One cluster termed "C850" – consists of 16 rocket bodies and 16 payloads that share a similar orbit at 850 km and 72° inclination. The study found that a first-order collision between two of these clustered objects would create, on average, approximately 16,000 pieces of trackable (i.e., > 10 cm) debris. In contrast, a similar collision between two 3U cubesats would create, on average, only about 14 pieces of trackable debris. URL: https://commons.erau.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=l&article=1175&context=stm

[21] *See* Science, Risks in Space from Orbiting Debris, Liou and Johnson, Science (Jan. 2006). ("The current debris population in the LEO region has reached the point where the environment is unstable and collisions will become the most dominant debris-generating mechanism in the future. Even without new launches, collisions will continue to occur in the LEO environment over the next 200 years, primarily driven by the high collision activities in the region between 900- and 1000-km altitudes, and will force the debris population to increase.").

the inclusion of newly filed constellations in the most recent Ka-band processing round, along with further proposals from SpaceX and OneWeb for tens of thousands of new satellites each, the numbers only worsen. The potential disabling of satellite maneuverability by impacts from small debris only adds to the concern, and the invalidity of the zero-risk assumption. The findings of the recent NASA Large Constellation Study, over the course of a mere year, will now need to be revised.[22]

Finally, the impact of debris generation on human spaceflight appears to be fairly underdiscussed. A substantial amount of mass that was originally planned to be placed above 1000 km, will now be placed directly within the zone that facilitates a more rapid deorbit. This may be better for the long-term orbital debris overall, but it carries the unintended side effect that virtually all new debris generated will now pass through human-inhabited space on a compressed time scale, a debris-fall more akin to a waterfall than a trickle. A cloud of debris generated below 650 km would tend to descend together, at once, presenting a briefer but more serious threat in the short term. Debris from the 2009 Iridium-Cosmos collision, which occurred at about 800 km, registered over 40 close passes to the ISS in the month of April, 2011 alone.[23] In 2012, the ISS conducted three collision avoidance maneuvers to avoid debris from Iridium-Cosmos and FY-1C, the most of any year in its history.[24]

Kepler acknowledges that this discussion concerns not just the collision risk, but also the collision consequences of the Modification. However, considering specifics pertinent to this case,

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[22] *See* Liou *et al.*, *NASA ODPO's Large Constellation Study*, Orbital Debris Quarterly News, vol. 22, issue 3, 2018 at 4-7.

[23] *See* NASA Technical Reports Server, *Human Spaceflight Conjunction Operations*, (June 2011). *See also* NASA Technical Reports Server, *USA Space Debris Environment, Operations, and Policy Updates*, (Feb. 2011) (The Iridium-Cosmos collision and the intentional destruction of Fengyun-1C together accounted "for 36% of the total number of cataloged objects residing in or traversing low Earth orbit" in 2011).

[24] *See* NASA Technical Reports Server, *The Orbital Debris Problem and the Challenges for Environment Remediation*, July 2013.

including the raw scale and spatial density of the system, a failure to consider the material inadequacy of the zero-risk assumption with the real impacts to the debris environment could represent a shirking of the Commission's responsibility to ensure the integrity and safety of orbit. For that, the Commission should require at least the bare minimum of information discussed here to assess cases where the size and spatial density of a constellation strain the effectiveness of the zero-risk assumption. Such information would not only provide certainty to operators sharing the orbital space under discussion, but also allow the Commission to better carry out its duties in assessing the proposed Modification against the public interest. For the reasons outlined here, Kepler is concerned that the introduction of over 730,000 kg into a highly dense shell around 550 km, on top of the 1,584 satellites and numerous other systems already authorized in that zone, will form a fragile framework vulnerable to cascade. Kepler urges the Commission to properly account for the potentially unprecedented level of risk that the Modification introduces in its assessment.

Respectfully Submitted

/S/ Nickolas G. Spina

Nick G. Spina

Director, Launch & Regulatory Affairs

CERTIFICATE OF SERVICE

I, Nickolas Spina, hereby certify that on July 13, 2020, a true and correct copy of this Petition was sent via electronic mail to the following:

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* Sent by electronic mail due to COVID-19.